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11 AUTHORS, INCLUDING:

Caspar J. M. Hewett

Newcastle University

Anthony J. Parsons

The University of Sheffield

Graham Hargrave

Loughborough University

Edward J Long

Loughborough University

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The Importance of Simulating Changes in Topography in Process-based Soil Erosion Modelling: Implications for Landscape Evolution Modelling

Caspar J.M. Hewett (1), John Wainwright (1), Anthony J. Parsons (2), James R. Cooper (3), Ben Kitchener (2), Graham K. Hargrave (4), Edward J. Long (4), Yuichi Onda (5), and Jeremy Patin (5)

(1) Department of Geography, University of Durham, United Kingdom (caspar.hewett@dur.ac.uk), (2) Department of Geography, University of Sheffield, United Kingdom, (3) Department of Geography and Planning, University of Liverpool, United Kingdom, (4) School of Mechanical and Manufacturing Engineering, Loughborough University, United Kingdom, (5) University of Tsukuba, Tsukuba, Japan

A model has been developed to begin to fill the gap between existing soil-erosion and landscape-evolution models. Most soil-erosion models are high resolution, run on short time scales and are based on realistic process dynamics but do not update topography. In contrast landscape-evolution models are typically run on large areas over long periods but use highly simplified process models. In the current study an existing process-based soil-erosion model has been adapted that has been adapted to allow prediction of changes in topography in order to begin to bring these two types of model together. The model, MAHLERAN (Model for Assessing Hillslope-Landscape Erosion, Runoff And Nutrients) employs a conceptualization of soil-erosion processes which takes account of the fact that interrill flow on hillslopes is dominated by rolling or sliding along surfaces or in short steps akin to movement of bedload. Parameterizations of the different soil detachment and transport mechanisms that occur under rainfall are used to better capture the reality of soil-erosion processes. Overland flow is modelled using a kinematic wave approximation to the 2D shallow water equations combined with the Darcy-Weisbach flow equation to calculate velocity. Flow is assumed to be in direction of steepest descent in cardinal directions on a simple finite difference grid. The model includes an infiltration component based on the Smith and Parlange approach. Sediment is divided into six size classes in order to account for differing behaviour of particles of different size and is transported by splash, flow (concentrated/unconcentrated) or in suspension. Detachment is assumed to occur in one of three ways: (1) as a function of raindrop detachment alone when there no overland flow; (2) raindrop detachment modified to account for surface layer effects in the case of unconcentrated overland flow; and (3) concentrated erosion when flow is turbulent. Deposition is modelled using a transport-distance approach described by an exponential distribution function. The initial, static version of the model has been modified so that surface topography during a storm event may be updated at regular intervals or at every time step. The dynamic version of the model makes it possible to test how important topographic change is in controlling runoff and erosion processes in events of different magnitudes or over a series of consecutive events. Results from field data under natural conditions in Japan and USA and experimental data from plot-scale rainfall simulation experiments at the University of Tsukuba Large Rainfall-Simulation Facility have been used to evaluate the model. Furthermore, sensitivity analysis is carried out to assess the impacts of dynamic changes in topography on flow and particle transport more generally. The introduction of topographic change during storms provides a more realistic model of what happens in heavy storm conditions especially on steep slopes and could be used to inform the development of improved landscape-evolution models over longer simulation periods.